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Technical Memorandum

U. S. NAVY
UNIVERSAL LOCATOR AIRBORNE INTEGRATED DATA SYSTEM
AN/AYQ-8(V)

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A prototype Universal Locator Airborne Integrated Data System (ULAIDS) has been developed by the U. S. Naval Air Systems Command under the Program Management of NAVAIRTESTCEN. The ULAIDS was designed to monitor, record, and display up to 400 aircraft sensor parameters, including aircrew radio and intercommunications audio. The ULAIDS is a distributed microcomputer system consisting of five smart multiplex terminals interconnected with dual MIL-STD-1553 multiplex data buses. It is universal and modular such that it can be expanded (or compressed) within the multiplex terminals and on the multiplex data bus and is adaptable to all aircraft type applications. The

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multiplex terminals can act as either distributed terminals using a dynamic bus allocation protocol or as remote terminals using a central computer command response protocol. The output terminals or subsystems consist of a maintenance recorder, a flight incident recorder (currently implemented in nonvolatile solid state), and a cathode ray tube display. A ground-based minicomputer system provides recorder playback and detailed maintenance/mishap/crash diagnostics/analysis. The ULAIDS is predicted to have high reliability, maintainability, efficiency, and cost effectiveness.

PREFACE

A prototype Universal Locator Airborne Integrated Data System (ULAIDS) has been developed by the U. S. Naval Air Systems Command under the Program Management of NAVAIRTESTCEN. The ULAIDS was designed to monitor, record, and display up to 400 aircraft sensor parameters, including aircrew radio and intercommunications audio. The ULAIDS is a distributed microcomputer system consisting of five smart multiplex terminals interconnected with dual MIL-STD-1553 multiplex data buses. It is universal and modular such that it can be expanded (or compressed) within the multiplex terminals and on the multiplex data bus and is adaptable to all aircraft type applications. The multiplex terminals can act as either distributed terminals using a dynamic bus allocation protocol or as remote terminals using a central computer command response protocol. The output terminals or subsystems consist of a maintenance recorder, a flight incident recorder (currently implemented in nonvolatile solid state), and a cathode ray tube display. A ground-based minicomputer system provides recorder playback and detailed maintenance/mishap/crash diagnostics/analysis. The ULAIDS is predicted to have high reliability, maintainability, efficiency, and cost effectiveness.

APPROVED FOR RELEASE

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1. Introduction

Airborne Integrated Data Systems (AIDS) development in the U.S. Navy did not begin until the early 1970's. The first Navy system was the Inflight Engine Condition Monitoring System (IECMS) developed to monitor the Detroit Diesel Allison TF-41 engine in the Vought A-7E Corsair aircraft. Also, during the early 1970's, the U.S. Navy developed a deployable/survivable Flight Data Recorder/Crash Position Locator (FDR/CPL). This system, designated the AN/ASH-20(V), was subsequently installed in some of the Navy multiengine aircraft (P-3B, E-2B, C-2A, and KC-130R). Advanced integrated cockpit displays were also being developed for the Navy/McDonnell F/A-18 Hornet aircraft. It was not until late 1975 that the Navy decided to proceed with the development of a complete AIDS that could integrate aircraft engine, airframe systems, cockpit display, and flight incident (data) monitoring. Consequently, an engineering development program, designated the Universal Locator Airborne Integrated Data System (ULAIDS), was funded by the U.S. Navy Chief of Naval Operations to be administered by the Naval Air Systems Command (NAVAIRSYSCOM) under the program management of NAVAIRTESTCEN. Figure 1 shows the Navy AIDS program genesis and relationships.

2. The Concept Objectives and Goals

The concept objectives of ULAIDS was to develop a system that would integrate all aircraft monitoring, recording, and display functions into a flexible single system to provide a standardized and cost effective avenue for future weapon system applications. The ULAIDS would be designed around the MIL-STD-1553 mutliplex data bus utilizing state-of-the-art technology advances in microprocessing, microelectronic memories, and data bus management (software) techniques. The ULAIDS hardware and software would be flexible and modular such that any of several subsystem combinations could be used in any aircraft type. The ULAIDS would also be designed for internal module growth and subsystem growth to expand sensor parameter signal conditioning and memory capacity. The ULAIDS would be fully documented (specifications, drawings, etc.) for future military aircraft procurements. The ULAIDS goals were to increase flight safety, mission effectiveness, aircraft availability, logistics efficiency, and cost effectiveness through real-time aircraft systems monitoring and postflight recorded data analysis.

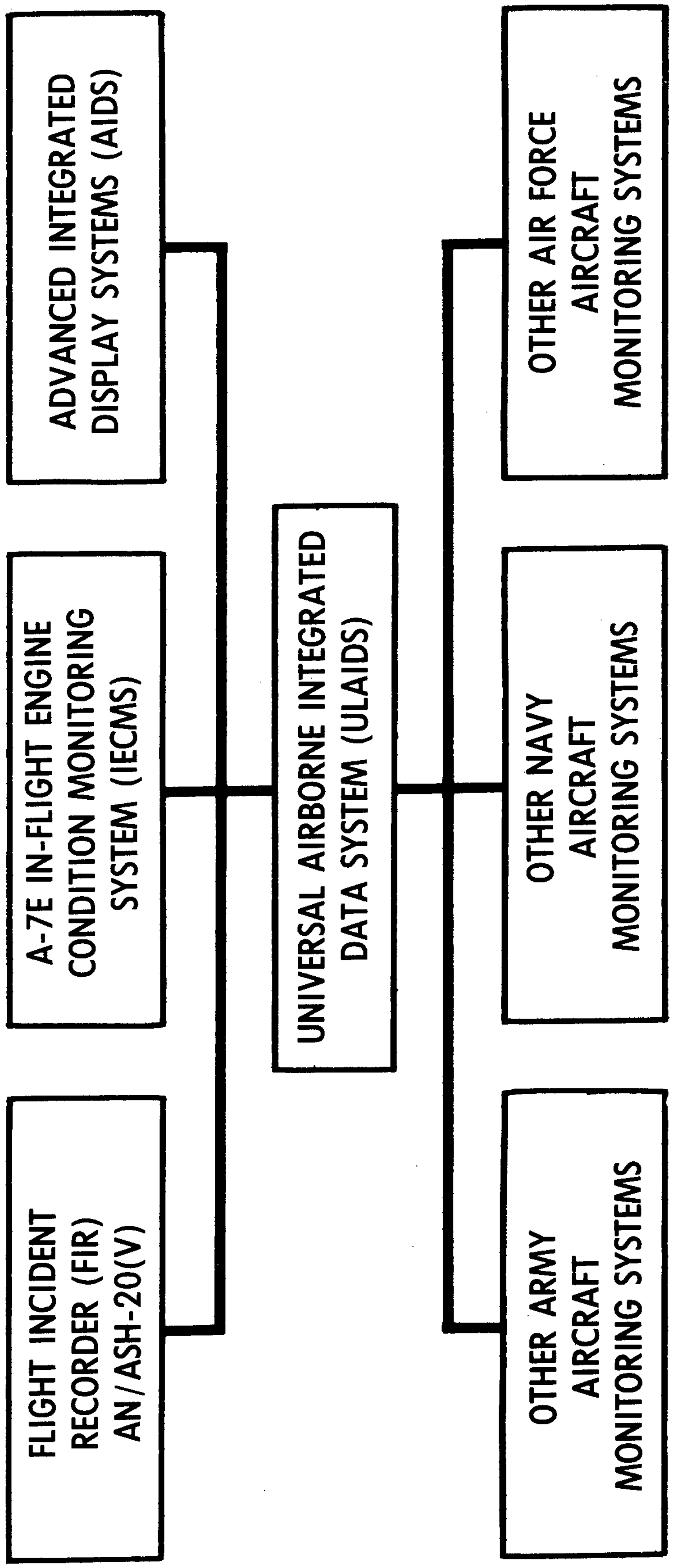

Figure 1
Navy Program Genesis and Relationships

3. Program Organization and Management

The ULAIDS program was organized jointly by NAVAIRSYSCOM and NAVAIRTESTCEN to maximize technical and managerial expertise in the most efficient manner. NAVAIRSYSCOM designated NAVAIRTESTCEN (Aircrew Systems Advanced Technology) as the program managers with technical design and funding control including contractual authority. As shown in figure 2, NAVAIRTESTCEN enlisted the technical support of in-house personnel and personnel from several Navy field activities. This matrix type program management group, although initally difficult to organize, proved to be very successful and efficient. The first task of the program management team was to establish a basic system concept and draft prototype procurement specifications. All documentation, including seven specifications, advanced procurement plan, test, and evaluation plan, integrated logistics support plan, contract documentation, and contract evaluation criteria, was completed within 2 months. A competitive Request for Proposal (RFP) was issued in March 1976 and, after extensive proposal evaluations, a cost plus fixed fee (CPFF) contract was awarded in September 1976 to Conrac Corporation Systems-East Division to design and manufacture the prototype ULAIDS. The ULAIDS design progress proceeded well until March 1977, at which time the contractor experienced difficulties resulting in a substantial projected cost growth. Design progress was slowed for approximately 7 months until the contract was renegotiated to a Firm Fixed Price (FFP) in October 1979. All ULAIDS hardware and software design and fabrication was completed in June 1979. Environmental qualification testing (MIL-E-5400, Class 2) and interim acceptance testing was completed in October 1979. The ULAIDS was delivered to NAVAIRTESTCEN in March 1980. Subsequently, the ULAIDS has undergone extensive Navy laboratory testing and has been integrated with the Navy/Sperry-Univac Solid State Flight Incident Recorder. During the contract phase, the Navy program management team closely monitored the ULAIDS development through monthly design reviews, documentation reviews, telephone communications, and test witnessing.

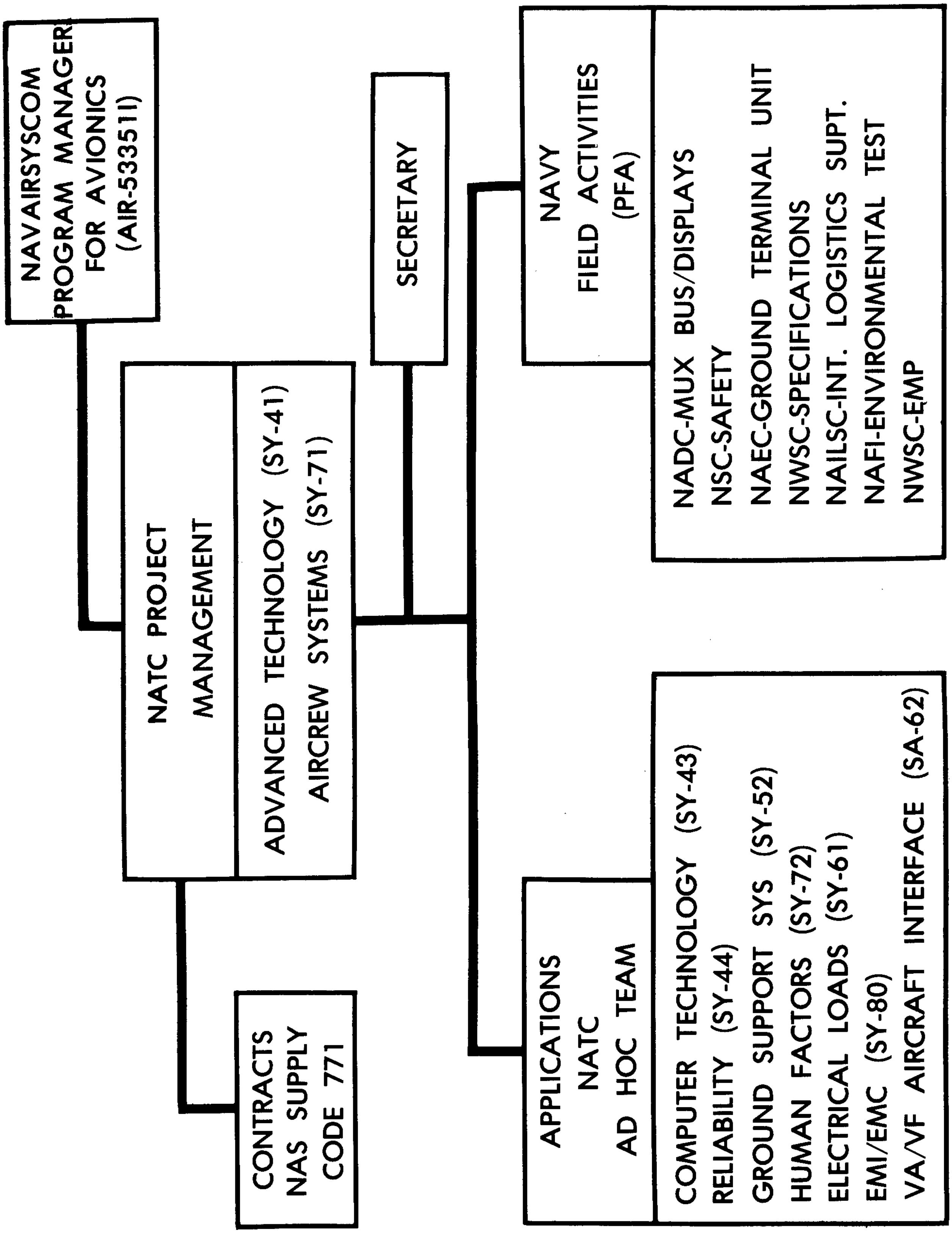

Figure 2
ULAIDS Program Organization

4. System Design

The ULAIDS design concept was originally developed by the U.S. Navy Program Management team; however, many changes evolved during the contract development phase. The design evolution and final hardware/software configuration is described below:

4.1 Architecture

The original Navy ULAIDS design concept was to develop a system with the following architecture:

Dual redundant multiplex data bus (MIL-STD-1553A).

Command response protocol.

Central comptuer.

Remote terminals.

However, with the advent of MIL-STD-1553B and more sophisticated microprocessors and memories, it became apparent that a more efficient system architecture would utilize a distributed microcomputer arrangement that operated with a command response dynamic allocation protocol. Therefore, as shown in figure 3, the ULAIDS architecture evolved as follows:

Dual redundant multiplex data bus (MIL-STD-1553A/B).

Command response dynamic bus allocation protocol.

Distributed microcomputers.

Central computer compatible.

Remote terminal compatible.

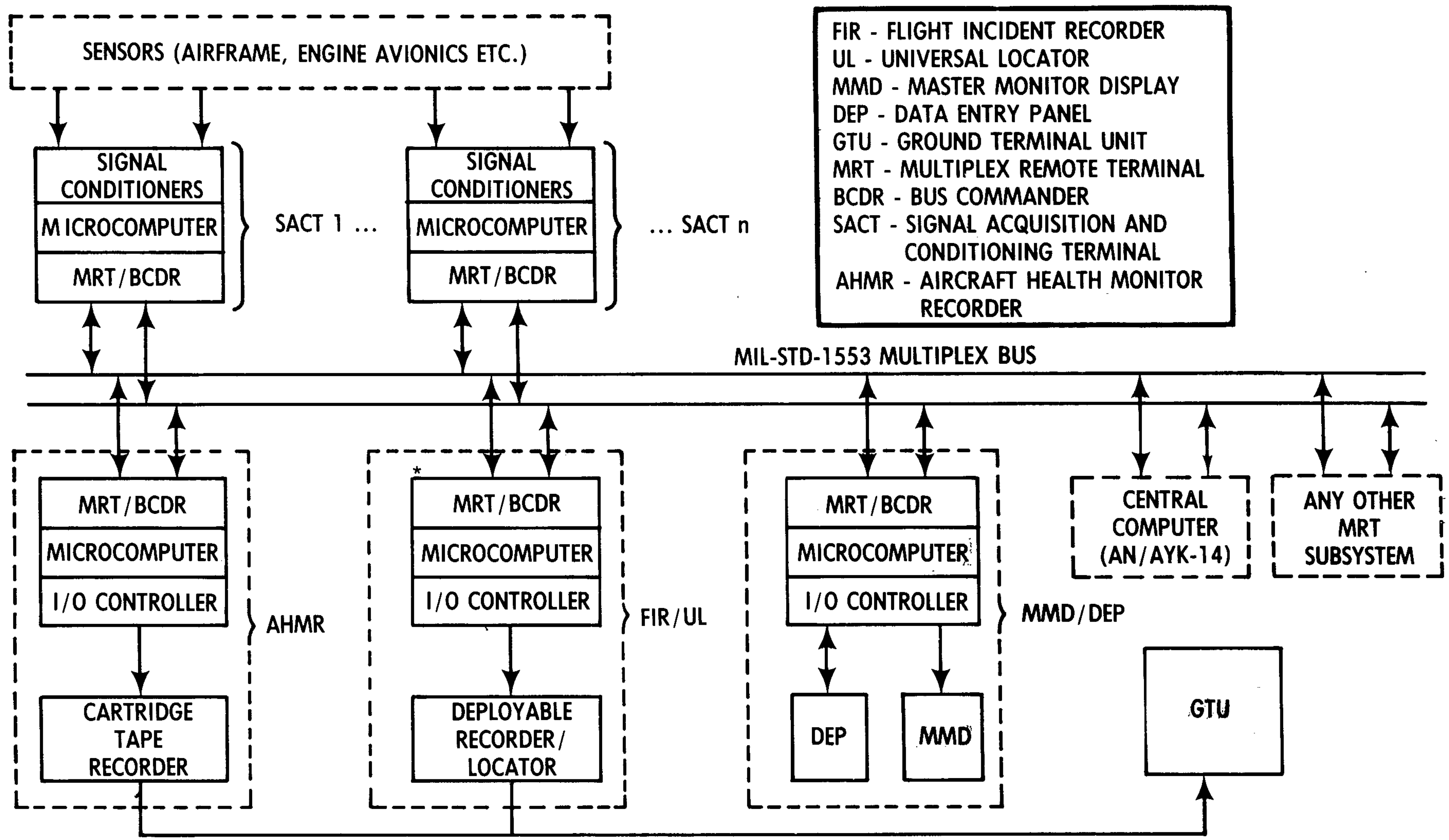

Figure 3
ULAIDS Functional Diagram, Distributed Microcomputer System

4.2 System and Subsystem Operation

Aircraft system parameter signals are generated by sensors in the host aircraft and are transmitted to the Signal Acquisition Conditioning Terminals (SACT's) in either analog or digital form. The SACT's provide signal converting, processing, and multiplexing onto one of the two redundant MIL-STD-1553 multiplex data buses. Each ULAIDS subsystem contains a bit-slice microprocessor bus controller; a second microprocessor that performs data collections, real-time processing, BIT, timing and control functions; and sufficient volatile and nonvolatile memory to provide software program storage and data buffering. These completely smart subsystem terminals can operate either as distributed processing terminals or as remote terminals. When operating in the normal distributed processing mode, the bus controller function is passed from one subsystem to another. Data received by each subsystem, when in control of the bus, is transferred to other subsystems as required. The ULAIDS input/output subsystem terminals are shown in figure 4 and are further described as follows:

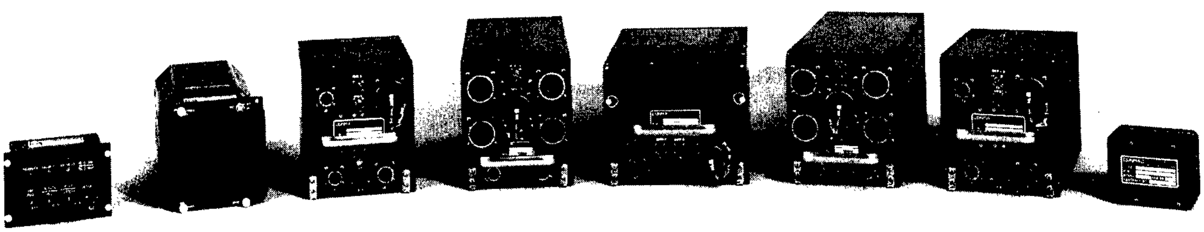

Figure 4
ULAIDS Airborne Hardware

4.2.1 Aircraft and Engine Signal Acquisition and Conditioning Terminals

The SACT's accept signals from various aircraft subsystems and perform the preconditioning, filtering, amplifying, conversion, and parameter exceedance limit monitoring. They provide ratio voltage ranges required for transducer excitation and internal data transfer operations. The SACT's are configured with input modules having sufficient channels to accommodate the various typical signal combinations. The input impedance of the SACT's are sufficient to isolate the data subsystem from the aircraft subsystems should internal malfunction occur. The output of the SACT's interface with the MIL-STD-1553 multiplex data bus. The SACT's as shown in figure 5 were designed specifically for ULAIDS. The prototype SACT's weigh 22 lb each and are housed in 3/4 ATR long chassis which can be reduced in production to approximately 16 lb and 3/4 ATR short chassis.

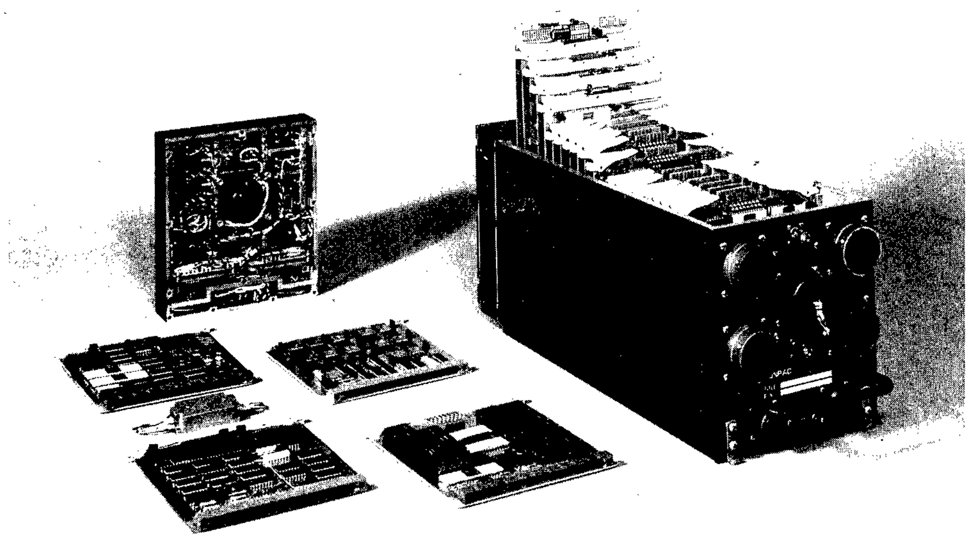

Figure 5
Signal Acquisition and Conditioning Terminal

4.2.2 Master Monitor Display/Data Entry Panel

The Master Monitor Display/Data Entry Panel (MMD/DEP) accepts data from the MIL-STD-1553 multiplex data bus via a multiplex terminal (MT) to present flight critical and other aircraft health status in tableau form on a cathode ray tube display. Symbol generation functions are incorporated in the display to provide alphanumeric and other required symbology upon command. The MT and DEP were designed specifically for ULAIDS. The MMD is an off-the-shelf display that weighs 16 lb in a 3/4 ATR long chassis. The prototype DEP weighs 2 lb in a 1/4 ATR short chassis which can be integrated into the MMD for production. The prototype MT weighs 14 lb in a 3/4 ATR short chassis which can be reduced in production to approximately 8 lb. The MMD/DEP as shown in figure 6 will display the following categories of information:

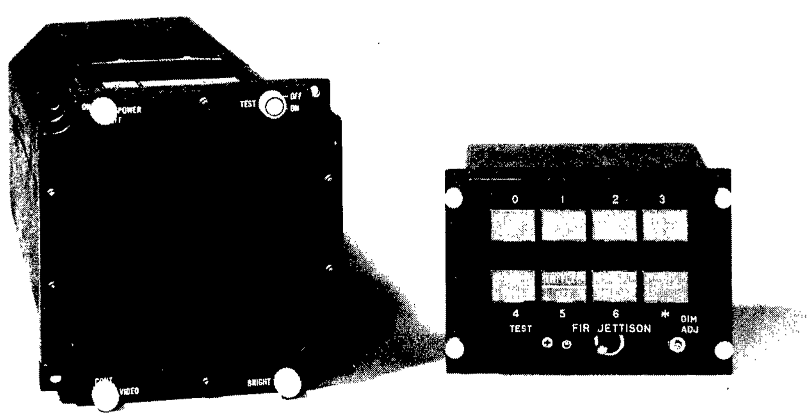

Figure 6
Master Monitor Display and Data Entry Panel

4.2.2.1 Data Priority I

Information which is catastrophic, essential to safety of flight, or mission abort in nature. This data is displayed automatically on the MMD.

4.2.2.2 Data Priority II

Information which indicates an aircraft system/component sensor parameter failure or exceedence that results in a degraded mode of operation. This data is displayed automatically on the MMD.

4.2.2.3 Data Priority III

All current sensor parameter data (engineering units) received by the SACT's. Failed and limit exceeded parameters are enunciated with a flashing asterisk. This data is called up on the MMD through the DEP and is used primarily for flightline maintenance purposes.

4.2.2.4 History Data

Failed and limit exceeded parameters with error counts and associated times the errors occurred during the flight are stored in nonvolatile metal nitride oxide semiconductor (MNOS) memory and can be displayed to maintenance personnel subsequent to the flight. This data is called up on the MMD through the DEP.

4.2.2.5 Reference Data

A listing of aircraft preflight, postflight, and emergency procedures that is called up on the MMD through the DEP.

4.2.2.6 Automatic BIT

Constantly displays Priority I, Priority II, and BIT status. If BIT has failed, a display test routine can be called up through the DEP to isolate the failure to the ULAIDS module or PCB level.

4.2.3 Aircraft Health Monitor Recorder

The Aircraft Health Monitor Recorder (AHMR) accepts all sensor parameter data from the MIL-STD-1553 multiplex bus for processing and recording on magnetic tape cassette. The normal recording mode is limit exceedance only; however, the system design allows for continuous and/or snapshot recording upon aircrew command through the DEP. The current AHMR was designed around an off-the-shelf digital magnetic tape deck with the bus interface, microprocessor, memory, and other electronics designed specifically for ULAIDS. The prototype AHMR weighs 24 lb in a full ATR chassis. A future version of the AHMR will be implemented in nonvolatile solid state memory to increase subsystem reliability, maintainability, and data handling efficiency. This new design will be integrated into the FIR/MT described in 4.2.4. The prototype AHMR and associated cassette playback interface unit (see 4.2.5) is shown in figure 7.

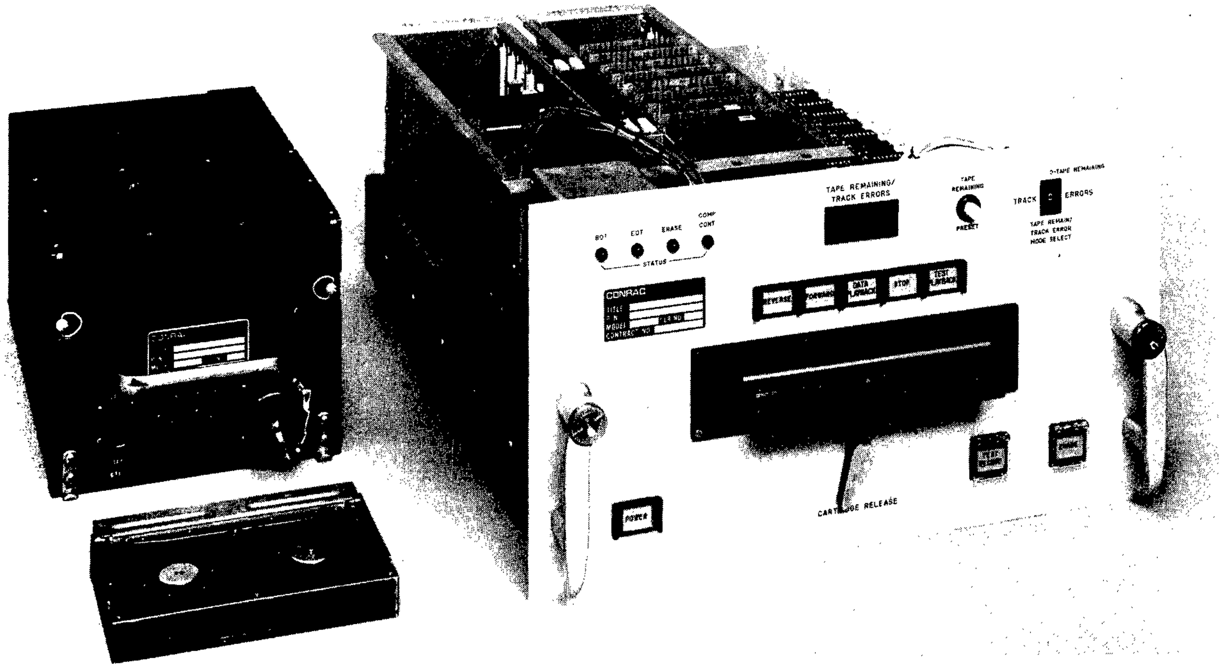

Figure 7
Aircraft Health Monitor Recorder with
Ground/Playback Interface Unit

4.2.4 Flight Incident Recorder/Crash Position Locator

The Flight Incident Recorder (FIR) Multiplex Terminal (MT) accepts and processes selected sensor parameters that are essential to aircraft safety of flight and mishap/crash analysis. The FIR/MT also accepts and processes aircrew audio (intercommunications and radio communication). Both the sensor parameter data and the audio are transmitted to a deployable FIR/Crash Position Locator (CPL) to provide a nonvolatile recording of 30 min of sensor parameter data and 15 min of audio prior to mishap or crash. The U.S. Navy FIR/CPL is automatically ejected from the aircraft by ejection sensors (frangible switches, water activated switch, etc.) upon crash impact. The FIR/CPL is crash survivable, floatable, and transmits an emergency radio beacon signal (243 MHz) and a visual marker (strobe light). The ULAIDS FIR was originally implemented with an off-the-sheld, two channel, continuous loop, magnetic tape recorder that recorded 30 min of continuous digital sensor parameter and analog audio data. The ULAIDS FIR has since been replaced by a nonvolatile solid state FIR in approximately the same volume and weight envelope. The new solid state FIR utilizes six million bits of MNOS Block Organized Random Access Memory (BORAM) to store 30 min of continuous sensor parameter data and 15 min of compressed (silence edited) audio. The audio analog-to-digital conversion, audio compression, memory controlling, and addressing functions are performed in the MT to conserve volume and weight in the deployable FIR/CPL. The MT, FIR (magnetic tape unit), and associated playback interface unit (see 4.2.5) are shown in figure 8. The prototype MT weighs 14 lb in a 3/4 ATR short chassis. In production with the AHMR (see 4.2.3) integrated into the FIR/MT will weigh approximately 25 lb in a 3/4 ATR chassis. The six million bit solid state FIR currently weighs 3 lb in a volume of 62 cu in..

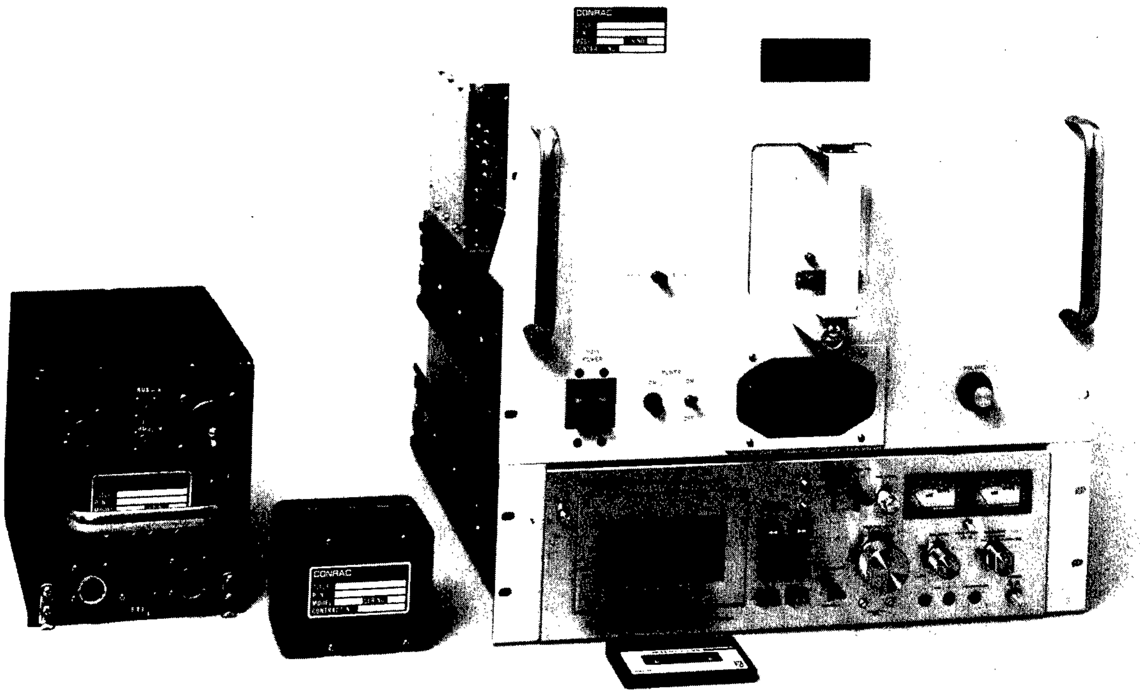

Figure 8
Flight Incident Recorder, Multiplex Terminal, and
Ground Playback Interface Unit

4.2.5 Ground Terminal Unit

The Ground Terminal Unit (GTU) accepts and processes data from the AHMR and FIR memory media. The GTU consists of a Digital Electronics Corporation (DEC) PDP-11/34 minicomputer interfaced with playback units for the AHMR magnetic tape cassette, the magnetic tape FIR, and the solid state FIR. Peripherals include a teletype terminal, a CRT terminal, a high-speed printer, and a plotter. The GTU is programmed to perform detailed maintenance diagnostics with the AHMR data and aircraft mishap/crash analysis with the FIR data. The GTU is shown in figure 9.

Figure 9
Ground Terminal Unit (PDP-11/34 Minicomputer, Playback Units, and Peripherals)

4.3 Flexibility and Modularity

The ULAIDS was designed to have maximum flexibility and modularity. It was designed to be universal to all new aircraft designs and readily integratable into existing aircraft avionic systems. In its simplest form, ULAIDS can consist of only one output subsystem, such as the AHMR, integrated into an existing aircraft avionic system. The ULAIDS can also be expanded to handle many more sensor parameters and provide greater data processing and memory capacity by adding SACT's and/or output terminals. The modularity and expansion capabilities are futher described below:

4.3.1 Printed Circuit Boards

All subsystem Printed Circuit Boards (PCB's) are designed to be the same size and interchangeable with standard signal conditioning, bus interface, microprocessing, and memory PCB's. Spare slots are provided in each subsystem for PCB growth. Each PCB is equipped with a built-on card puller and a test connector.

4.3.2 Power Supplies

All power supplies are designed to be the same size, interchangeable and easily removable from the subsystem chassis. A quiet single phase cooling fan is imbedded in the power supply.

4.3.3 Subsystems

Each ULAIDS subsystem is designed in optimum Air Transport Radio (ATR) sizes. All external connectors (except multiplex bus connectors) are standard high contact density conforming to MIL-C-38999. A standard test connector is provided that is compatible with the Navy Versatile Avionics Ship Test (VAST) facility or any other intermediate maintenance Automatic Test Equipment (ATE). Each subsystem is equipped with a standard and interchangeable mounting rack and removal/carrying handle.

4.3.4 Software

The ULAIDS is designed with standardized executive software that can be independently configured for each subsystem distributed microcomputer. It is table driven whenever possible allowing maximum flexibility to include or exclude features as required. The application software runs as independent tasks, subordinate to, and supervised by the executive software. The subsystem task lists are generated at configuration (assembly time) and are easily modified to add or drop tasks.

5. System Capabilities

The ULAIDS prototype currently monitors 183 sensor parameters and aircrew audio. This system can be expanded internally to handle in excess of 400 sensor parameters. By adding SACT's, the system can handle many more parameter signals until the multiplex bus becomes saturated. Other input/output functions not presently in ULAIDS that could be integrated are fatigue monitoring, navigation systems monitoring and display, weapons sysems display, and stores management. Current output capabilities are as follows:

5.1 Airborne/Real-Time Monitoring

The ULAIDS provides automatic instantaneous display and recording of all failed, limit exceeded, and degraded sensor parameters. It provides automatic alert displays of emergency procedures for each critical or precautionary situation. Selected parameters can be called up on the display that are redundant to conventional cockpit gauges, thus allowing gauge substitution. ULAIDS provides for airborne or flight line display recall of failed or limit exceeded parameters from a nonvolatile solid state memory for fault isolation and immediate maintenance. This can eliminate time and cost required for manual fault isolation and false component removals.

5.2 Postflight Analysis

The ULAIDS provides in-depth maintenance diagnostics through GTU analysis of the AHMR data. This computer analysis can be used to improve aircraft performance by optimization of the total aircraft system efficiency through subsystem timing/adjustment of engine fuel control, drag, and takeoff and landing performance. The GTU can provide valuable flight training information to pilots subsequent to each flight. The GTU diagnostics can provide forecasting information for aircraft maintenance and logistics support. Aircraft engine, system, subsystem, module, and component failures can be predicted and replaced before actual failure. Aircraft parts inventory can be more accurately predicted and provisioned. Through accurate forecasting, aircraft phased maintenance periods can be either extended or eliminated altogether.

5.3 Safety

The ULAIDS provides enhanced flight and systems safety through analysis and use of the FIR and AHMR data. Airborne system malfunctions and failures can be precluded by using data diagnostics, performance trending, and forecasting. Maximum aircraft safety can be realized when use of analysis data can be attributed to aircraft saves or crash prevention. The CPL also enhances aircrew survival safety by aiding search and rescue operations in the location of a crashed or ditched aircraft.

6. System Reliability and Maintainability

Since the prototype ULAIDS was designed and tested to production equipment requirements, a greater than normal degree of reliability and maintainability (R&M) has been achieved. Using empirical test data, reliability predictions of MIL-STD-756, and maintainability predictions of MIL-HDBK-472, the prototype ULAIDS has a predicted mean time between failure (MTBF) of 235 hr and a mean manhours to repair (MMTR) of 0.312 hr. The ULAIDS MTBF and MMTR can be improved considerably by replacing the AHMR and FIR magnetic tape decks with nonvolatile solid state memories since these are the least reliable components. For example, using a predicted MTBF of 10,000 hr for a solid state AHMR and FIR, the ULAIDS predicted MTBF is increased from 235 hr to 443 hr. Additional R&M could be achieved through the upgrading of microelectronic devices and subsystem production engineering.

7. Cost Savings Considerations

Some cursory life cycle costing (LCC) and cost benefits analyses (CBA) have been conducted on the ULAIDS and on other AIDS applications. A detailed LCC and CBA was conducted on ULAIDS integrated into the LAMPS MK III (SH-60B) Seahawk Helicopter. This LCC/CBA model was applied to all U.S. Navy aircraft. Also, other cost savings analyses have been applied to the U.S. Air Force C-5 MADAR system and two groups of TWA wide body aircraft. These cost savings figures are summarized below:

7.1 LAMPS MK III SH-60B Helicopter with ULAIDS (LCC)

Gross Expected Savings	$116,427,000
Initial Logistics Cost	-36,427,000
Net Estimated LCC Savings	$ 80,000,000
Cost Benefits Ratio	320%

7.2 All U.S. Navy Aircraft with ULAIDS (Annual)

Mishap/Crash Savings	$105,000,000
Nondefective Repair (A-799) Savings	10,000,000
Scheduled Maintenance Savings	20,000,000
Spare Parts Logistics Savings	15,000,000
Gross Annual Savings	$150,000,000
Initial Logistics Cost (Prorated 25 years)	5,000,000
Net Estimated Annual Savings	$145,000,000

7.3 U.S. Air Force C-5A with MADAR (Annual)

Gross Estimated Savings	$5,650,000
Estimated Nonrecurring and other Annual Costs	3,750,000
Net Estimated Annual Savings	$1,900,000

7.4 TWA Actual Annual Savings with AIDS (30 L-1011's and 10 B-747's)

Fuel	$343,000
Engines	428,000
Hydraulics	130,000
Electronics	9,000
Total Annual Savings	$910,000

7.5 TWA Projected Annual Savings (30 New Wide Body with AIDS)

Initial Investment	$9,000,000
Annual Recurring Cost	$1,000,000
Annual Savings (Beyond 1st year)	$6,500,000
Payback (Includes Recurring Cost)	2.25 years

8. Conclusions

The ULAIDS distributed microcomptuer MIL-STD-1553 multiplex data bus concept with command response/dynamic bus allocation protocol provides state-of-the-art hardware and software for maximum electronic efficiency, flexibility, and modularity. The prototype ULAIDS can be reduced or expanded for various aircraft types and systems integration. The ULAIDS is designed to provide automatic real-time airborne monitoring (display and recording) and fast postflight maintenance and safety analysis with a high degree of reliability and maintainability. The ULAIDS can provide considerable annual and life cycle cost savings when integrated into both military and commercial aircraft.

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CAPT R. ROOS (DAS-ENG4)
CFB OTTAWA NORTH
OTTAWA, ONTARIO, CANADA KIA 0K4
UNITED KINGDOM MINISTRY OF DEFENSE (1)
S/L P.E. SHARP
AIR ENG 12E (RAF)
OLD WAR OFFICE BUILDING
WHITEHALL, LONDON, U.K.
FEDERAL ARMED FORCES (1)
LTCOL H. U. GRANSDORFF
GENERAL FLIGHT SAFETY
POSTFACH 902500/501/07
5000 KOLN 90
FEDERAL REPUBLIC OF GERMANY